

## QUANTUM DOT BASED PIXEL ASSEMBLY

### RELATED APPLICATIONS

[0001] This application claims the benefit of priority of U.S. Provisional Application No. 62/647,969 filed Mar. 26, 2018 which is incorporated herein by reference.

### BACKGROUND

#### Field

[0002] Embodiments described herein relate to quantum dots. More particularly, embodiments relate to quantum dots in quantum dot LED displays.

#### Background Information

[0003] State of the art displays for phones, tablets, computers and televisions utilize glass substrates with thin-film transistors (TFTs) to control transmission of backlight through pixels based on liquid crystals. More recently emissive displays such as those based on organic light emitting diodes (OLED) have been introduced because they can have a faster response time, and be more power efficient, allowing each pixel to be turned off completely when displaying black or dark colors. Even more recently, quantum dot light emitting diodes (QD-LEDs) have been introduced as an alternative display technology, potentially being more power efficient than OLEDs.

[0004] Quantum dots are semiconductor materials where the size of the structure is small enough (e.g. less than tens of nanometers) that the electrical and optical characteristics differ from the bulk properties due to quantum confinement effects. For example, the emission properties of quantum dots are related to their size and shape in addition to their composition. When an electric field is applied to a QD-LED electrons and holes move into the quantum dot layer where the electrons and holes are captured in the quantum dots and recombine, emitting photos. The emission wavelength can be tuned by changing the size of the quantum dots. Typically, smaller quantum dots emit bluer light (higher energy) and larger quantum dots emit redder light (lower energy).

### SUMMARY

[0005] Display panel narrow band emission pixels and methods of fabrication are described. In an embodiment, a display panel narrow band emission pixel includes at least a first subpixel and a second subpixel. Each subpixel includes a corresponding reflective electrode (e.g. cathode), narrow band emission layer, and hole transport layer of different thickness over the corresponding reflective electrode and narrow band emission layer. Specifically, embodiments describe inverted pixel structures in which hole transport layers (HTL) with variable thicknesses, and hence tunable cavities, are located nearer a top transparent or semi-transparent anode layer, than to a more reflective cathode layer. The inclusion of a narrow band emitter facilitates inherent color gamut, which is less dependent on the micro cavity thickness compared to OLED. Location of the micro cavities closer the transparent anode layer may increase luminance. Additionally, a distance between the narrow band emission layers and reflective cathode layers can be minimized, reducing color shift vs. viewing angle.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a schematic side view illustration of an inverted pixel stack-up in accordance with an embodiment.

[0007] FIG. 2 is schematic side view illustration of an OLED stack-up.

[0008] FIG. 3 is a schematic side view illustration of a pixel stack-up in accordance with an embodiment.

[0009] FIG. 4 is a schematic side view illustration of a pixel stack-up in accordance with an embodiment.

### DETAILED DESCRIPTION

[0010] Embodiments describe narrow band emission pixels and display panels including the same. In particular, embodiments describe an inverted narrow band emission pixel stack. In an embodiment, a display panel narrow band emission pixel includes at least a first subpixel and a second subpixel, and a semi-transparent or transparent top electrode layer over corresponding first and second hole transport layers (HTLs). For example, the first subpixel may include a first reflective electrode, a first emission layer over the first reflective electrode, where the first emission layer is designed for a first narrow band emission wavelength range, and a first HTL characterized by a first thickness over the first emission layer. The second subpixel may include a second reflective electrode, a second emission layer over the second reflective electrode, where the second emission layer is designed for a second narrow band emission wavelength range that is different from the first narrow band emission wavelength range, and a second HTL characterized by a second thickness over the second emission layer, wherein the second thickness is different from the first thickness.

[0011] In one aspect, embodiments leverage the integration of narrow band emitters with tunable micro cavities to achieve systems with high current efficiency, while mitigating color shift over viewing angle. Specifically, embodiments describe inverted pixel structures, in which hole transport layers (HTL) with variable thicknesses, and hence tunable cavities, are located nearer a top transparent or semi-transparent anode layer, than to a more reflective cathode layer. Foremost, this allows for precise micro cavity tuning with the HTL to a narrow wavelength range. In addition, such a configuration may allow for pixel structures in which a thickness variation between the narrow band emission layers and the cathodes is much smaller than the wavelength of emitted light (e.g. one order magnitude less). This may lead to less deviation in color shift, and overall dependence of viewing angle on thickness variation.

[0012] In accordance with embodiments, narrow band emission may be defined by emission peaks of the emission layers of 35 nm or less full-width-at-half-maximum (FWHM). Narrow band emission layers may be achieved using emitters such as quantum dots specifically, though other materials may be used where appropriate. Narrow band emission is distinguishable from conventional OLED emission layers, which are commonly understood-as having a broadband internal spectrum. It has been observed that while broadband internal spectrum achieved with OLED may achieve good gamut, this is coupled with reduced efficiency at the narrowed output spectrum. Thus, embodiments may potentially achieve significantly higher current efficiencies compared to OLED displays.

[0013] In various embodiments, description is made with reference to figures. However, certain embodiments may be